Cognitive Psychology Lab

Marcus Cappiello

Agenda

- Introductions
- Tips for undergrad & grad school
- Syllabus
  - Course organization
- Intro to cognition
  - Why cognitive neuroscience?
  - Methods

Who am I?

Marcus Cappiello

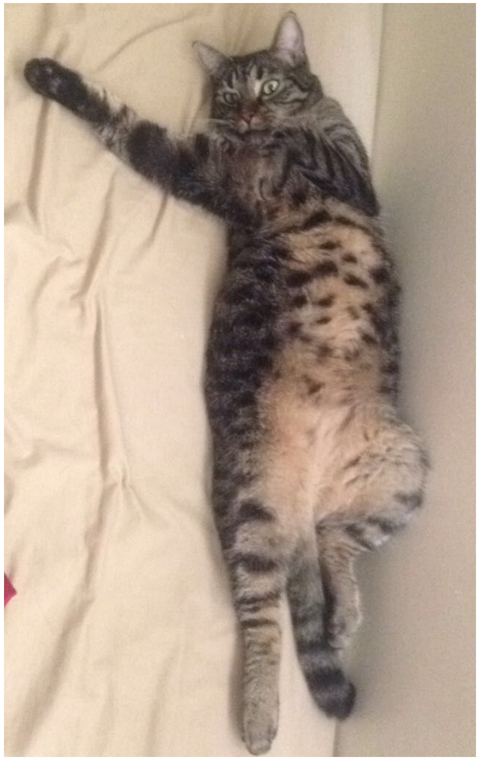
- PhD as of last term!
  - Cognitive Psychology
  - Memory
  - Email: marcuscappiellowork@gmail.com
  - OH: H735
    - Tuesdays after class (12pm)

Who are you?

- Name
- Year in School
- Major
- Something you like that starts with the first letter of your first name

Introductions

- Intermission entertainment: Daisy and Fiddler
  - Send me pet pictures?



Tips for getting into grad school

- GPA and GRE scores only matter to a point
- Most important:

1. Fit to the lab
    - Show interest in the lab material
    - Why would you be a good addition?
2. Lab experience
    - Join a lab as soon as possible
3. Letters of recommendation
    - One for you lab experience
    - One from a professor (whose class you did well in)

Tips for higher education

1. Sleep more than you study
2. Study more than you party
3. Party as much as possible

What can you do with cognitive psychology?

- Academia
  - Research professor
  - Teaching professor
- Industry
  - Military
    - Brain enhancement
  - Artificial intelligence
    - Best systems built by modeling the brain
  - Virtual reality
  - User interface research

Syllabus

- No exams!
- Class website on github
  - Most class materials posted here
- Grade based on class participation and papers
  - 1000 points total
  - 400 - 4 Labs, 100 points each
  - 100 - 4 Reflection Papers, 25 points each
  - 100 - Participation
  - 300 - Term Paper (research proposal)
  - 100 - Presentation

Reflection Papers

- 4 short papers in APA
- Based on reading, labs, and in-class lectures/discussions
  - Turned in on Titanium

Labs

- 4 labs
  - Start by running yourself on experiment in class
    - Coglab
  - For HW, run your friends or family
  - Combine data from all students into one final
    - I will show the data analysis methods in class
  - Write up the lab (APA)
    - Cover page, Intro, Methods, Results, Discussion, References

Participation

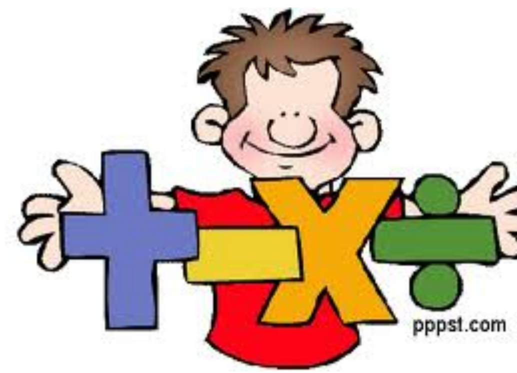
- Quizzes and participation

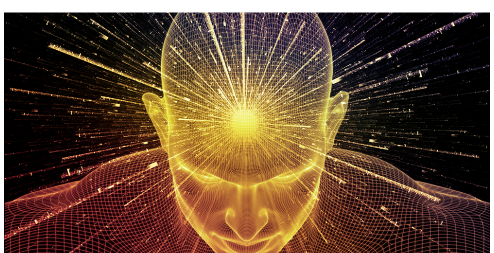
- Think, pair, share
- Each lecture there will be at least one TPS
- I will provide a prompt/question
  - Think about it on your own first (no talking)
  - Get together in a small group (min 2 in a group) and discuss what you think
  - Share with the class (included in your participation)

Research Paper/Presentation

- Term paper
  - Write a research proposal based on a literature review
    - Any topic you like covered in PSYC305 or PSYC305L
  - 8-12 pages with at least 6 references
  - I will help you refine your topics toward the end of the semester

Why Cognitive Psychology?





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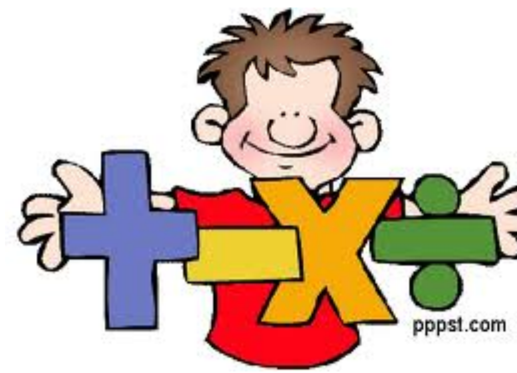
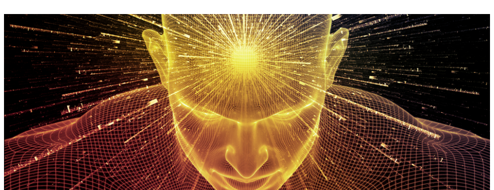
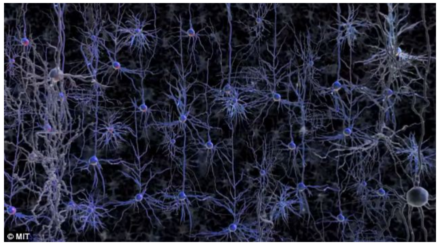
Why Cognitive Neuroscience?

- Politics
- Education
- Art
- Social interactions
- Science
- Philosophy
- *Everything we do*

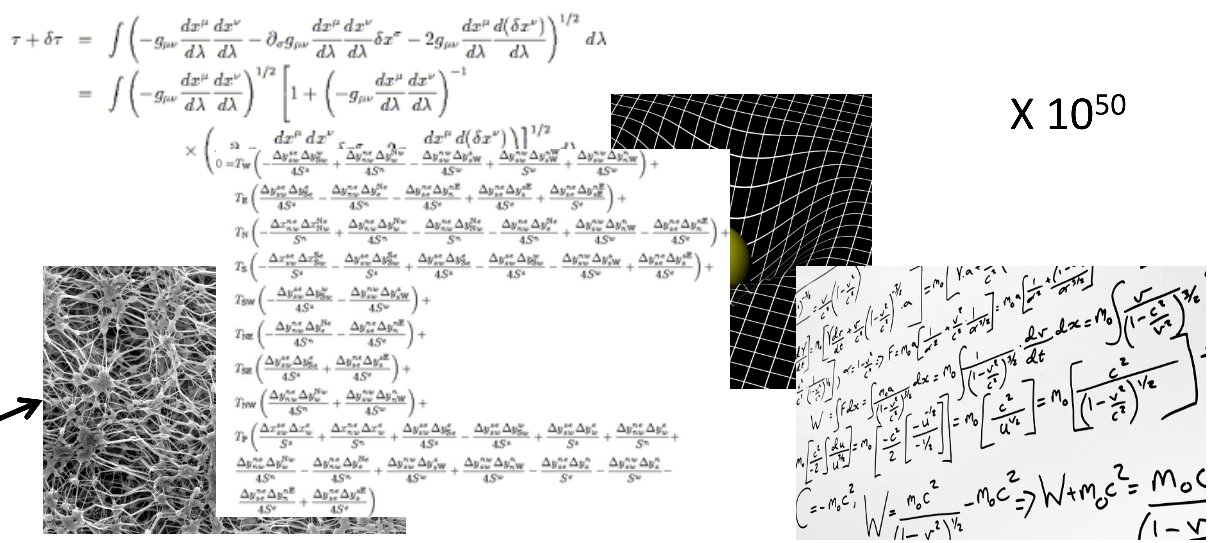




Cognitive neuroscience: goals



- To understand the brain!
- Model every cell interaction?
  - Then you have a brain again… haven't learned anything new
- Example: physics of a ball dropping



Cognitive neuroscience: goals

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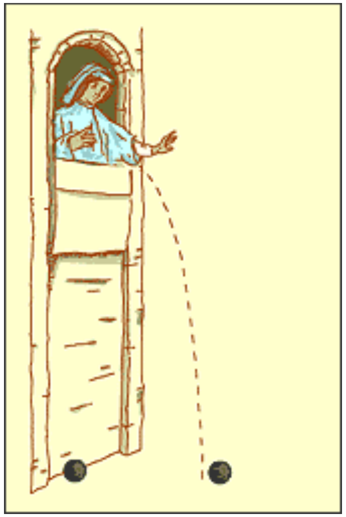


$$y = \underbrace{y_0}_{\text{initial position}} + \overbrace{v_0}^{\text{initial speed}} t + \frac{1}{2}at^2$$

Ball rolling
Two balls being juggled
Two people high fiving
ANY MOVING THING

Cognitive neuroscience: goals

- To understand the brain!
- Model every cell interaction?
  - Then you have a brain again… haven't learned anything new
- Instead, we want to *simplify*
  - Find underlying principles that can be used to describe the brain and cognition

The black box problem

Environment (Observable) → Black Box → Behavior (Observable)

?

Think, pair, share

- Come up with an experiment to test the following hypothesis:
  - Having one or more pets will improve your memory.

Black Box

=

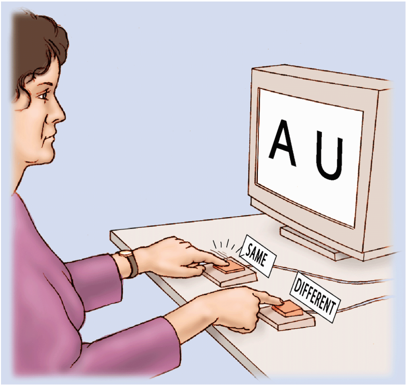
Cognitive Neuroscience

- Infer what is happening by looking at behavior
  - Behavioral paradigms
- Observe what happens when the box (the brain) is damaged
  - Case studies
- Observe what happens when we mess with the box
  - Brain stimulation
- Can image what is happening inside the box
  - Brain imaging

Behavioral paradigms

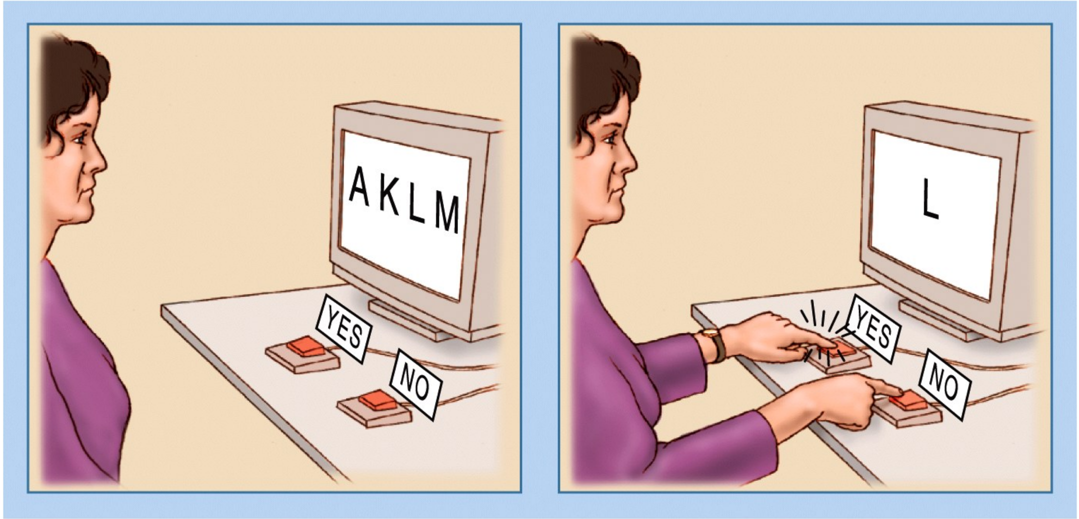
- Goal: Gain insight into how the mind works by observing behavior

- Approach: Give subjects a controlled cognitive task and measure performance
  - Response times (RTs)
  - Accuracy
  - Eye-movements



- Compare performance under different conditions

Evidence for serial processing: Sternberg short-term memory experiment



Ready?

KML

L

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Ready?

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UOPHG

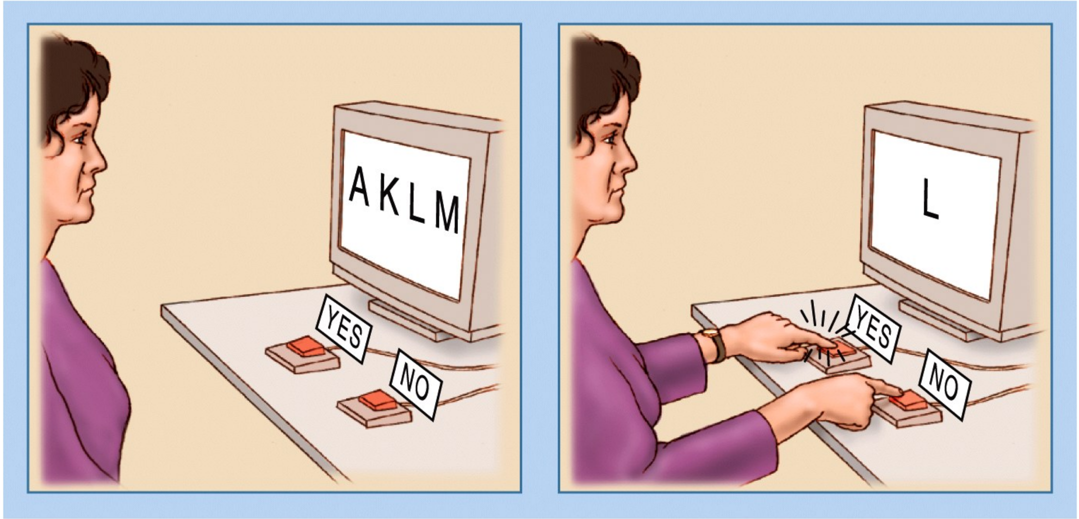
L

Ready?

ZYABQDIKBO

A

Evidence for serial processing: Sternberg short-term memory experiment



- Is the target letter compared in parallel or serially?
- What do the two operations **predict**?

Serial:

3 x 50 ms

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Serial:

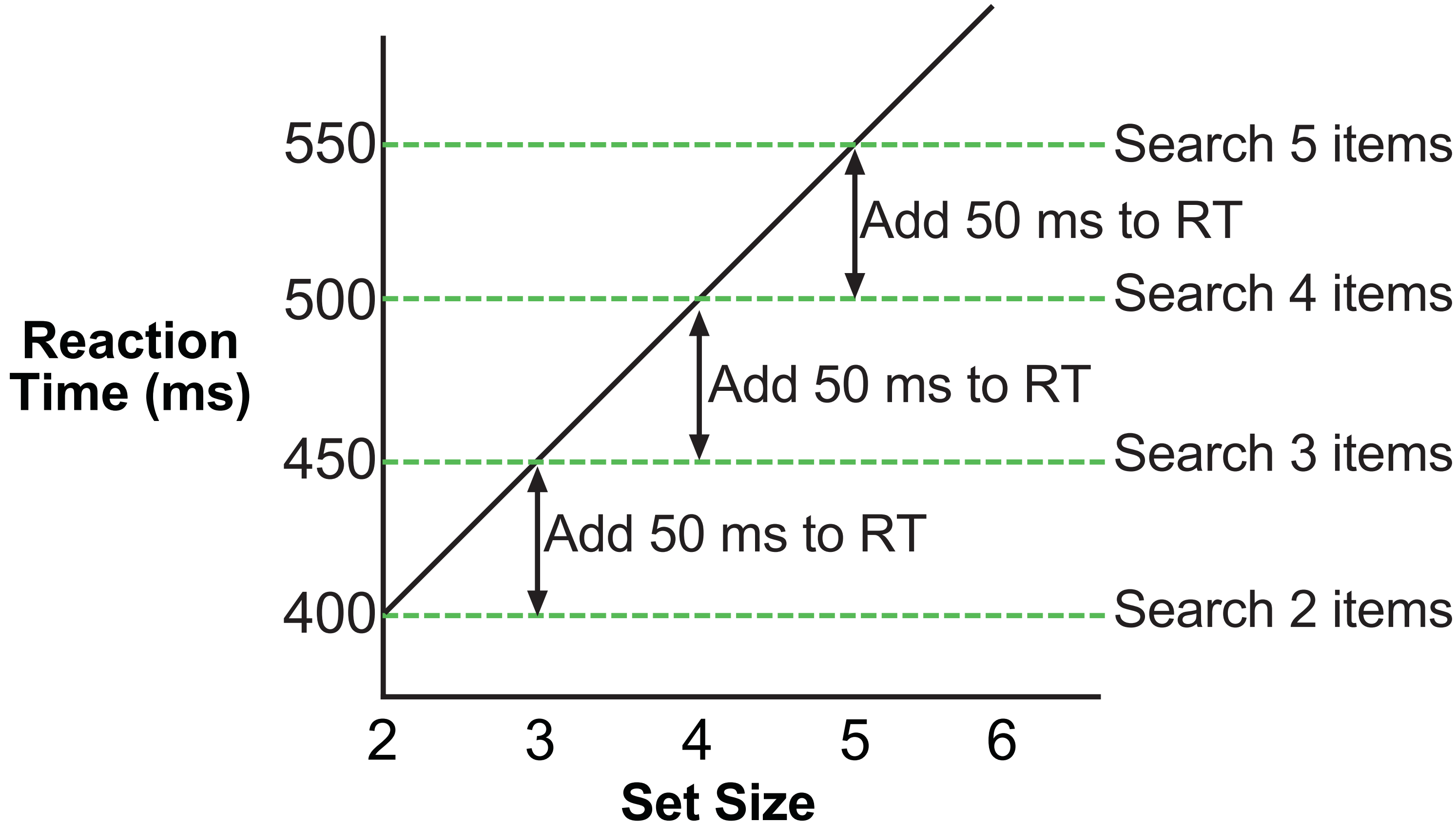
6 x 50 ms

ZYADBQ

D

Serial search: linear increase in RT

RT goes up by 50 ms for each item added to the array (Slope = 50 ms/item).



Parallel search: ?

Parallel:

1 x 50 ms

KML

L

Parallel:

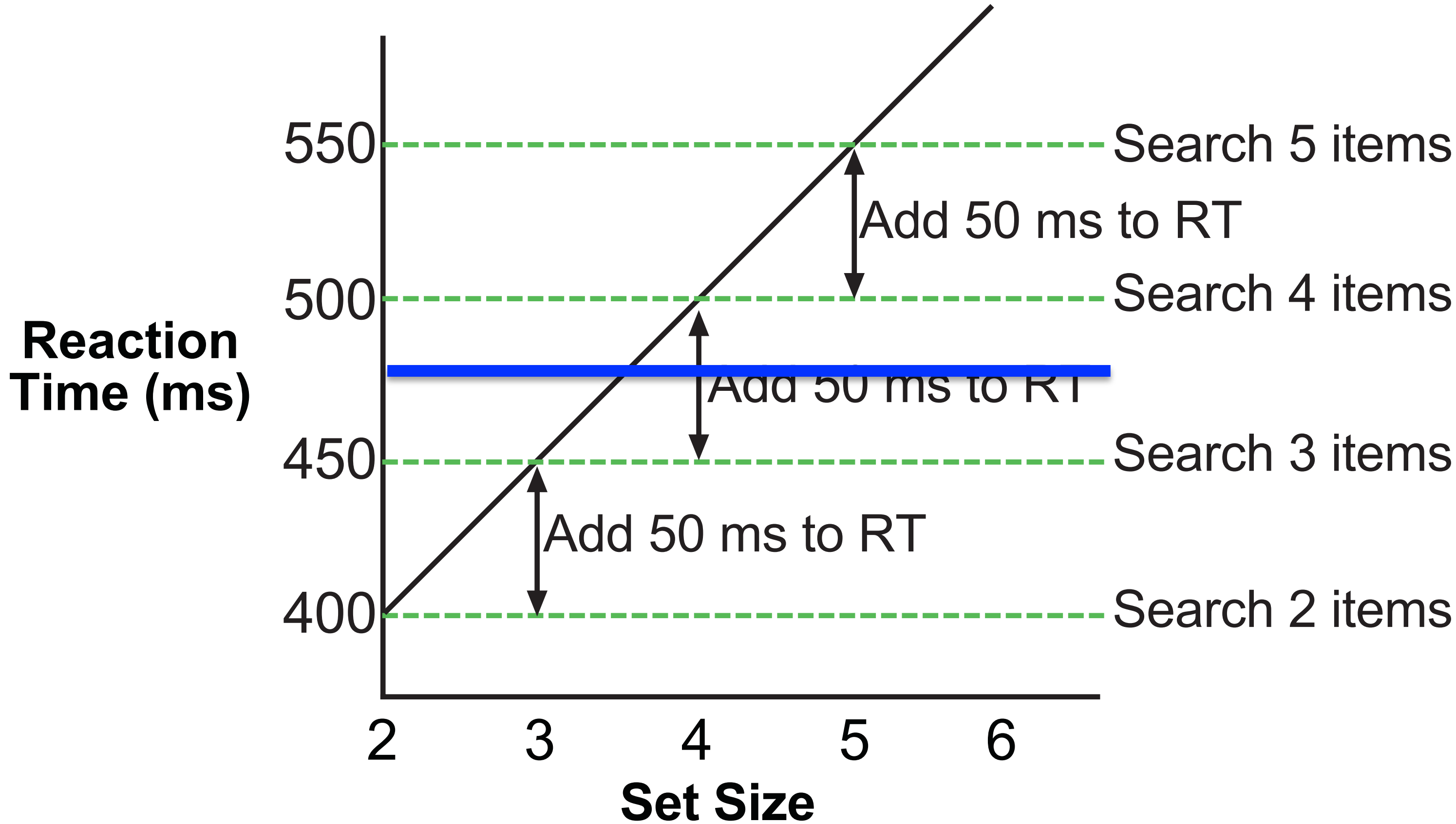
1 x 50 ms

ZYABQD

Q

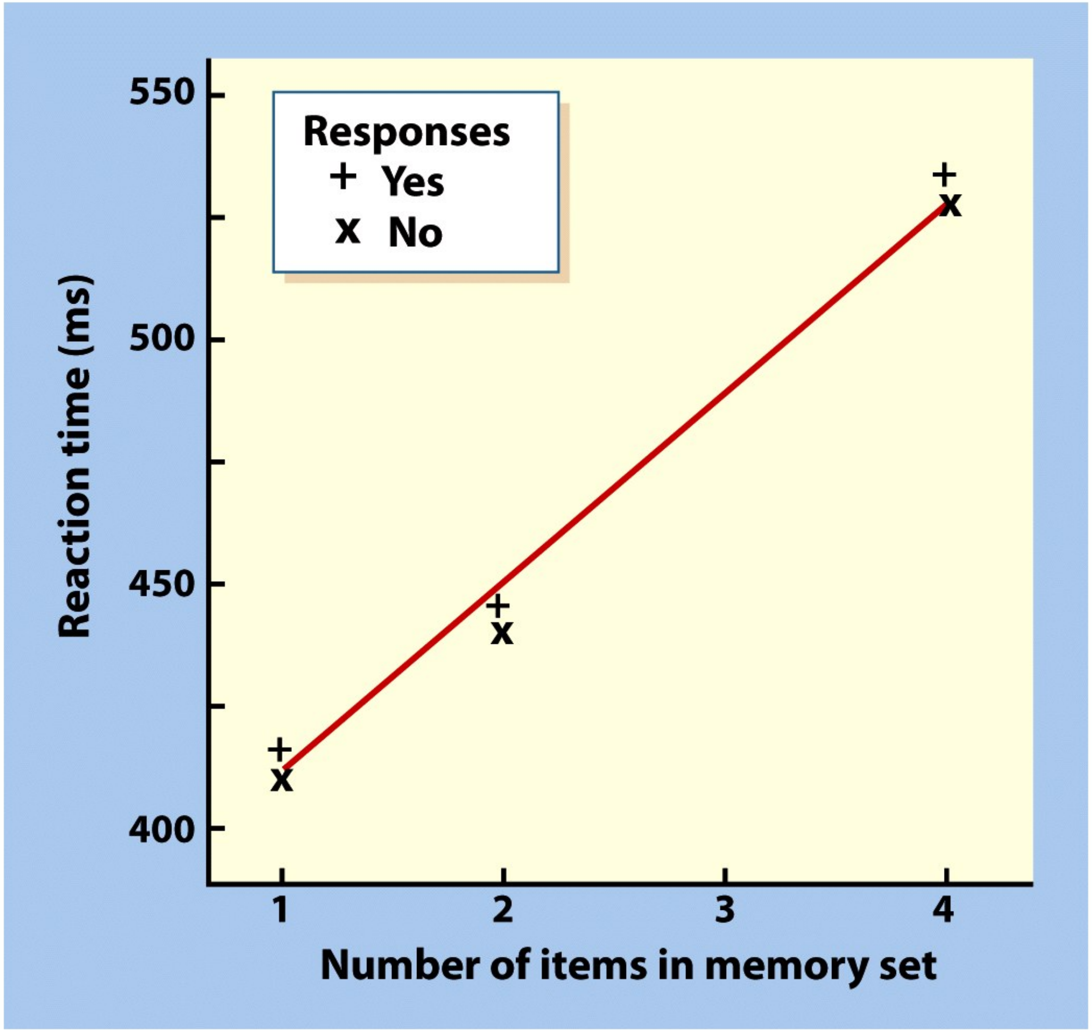
Serial search: linear increase in RT

RT goes up by 50 ms for each item added to the array
(Slope = 50 ms/item).



Parallel search: flat RT function

Results



Conclusions: memory items are scanned serially and exhaustively during memory search

Behavioral paradigms (cog psych)

Strengths	Weaknesses
Tests units of representations and consequences of manipulation processes (e.g. serial versus parallel memory search).	Cannot see how processes and representations are implemented; mechanisms inferred from behavior
Detailed models of relationship between inputs (sensory stimulation, instructions, environment) and outputs (behaviors, thoughts, actions). Provides experimental design and gives names to component functions.	Need overt responses
Can ask complex questions of awake, behaving humans.	

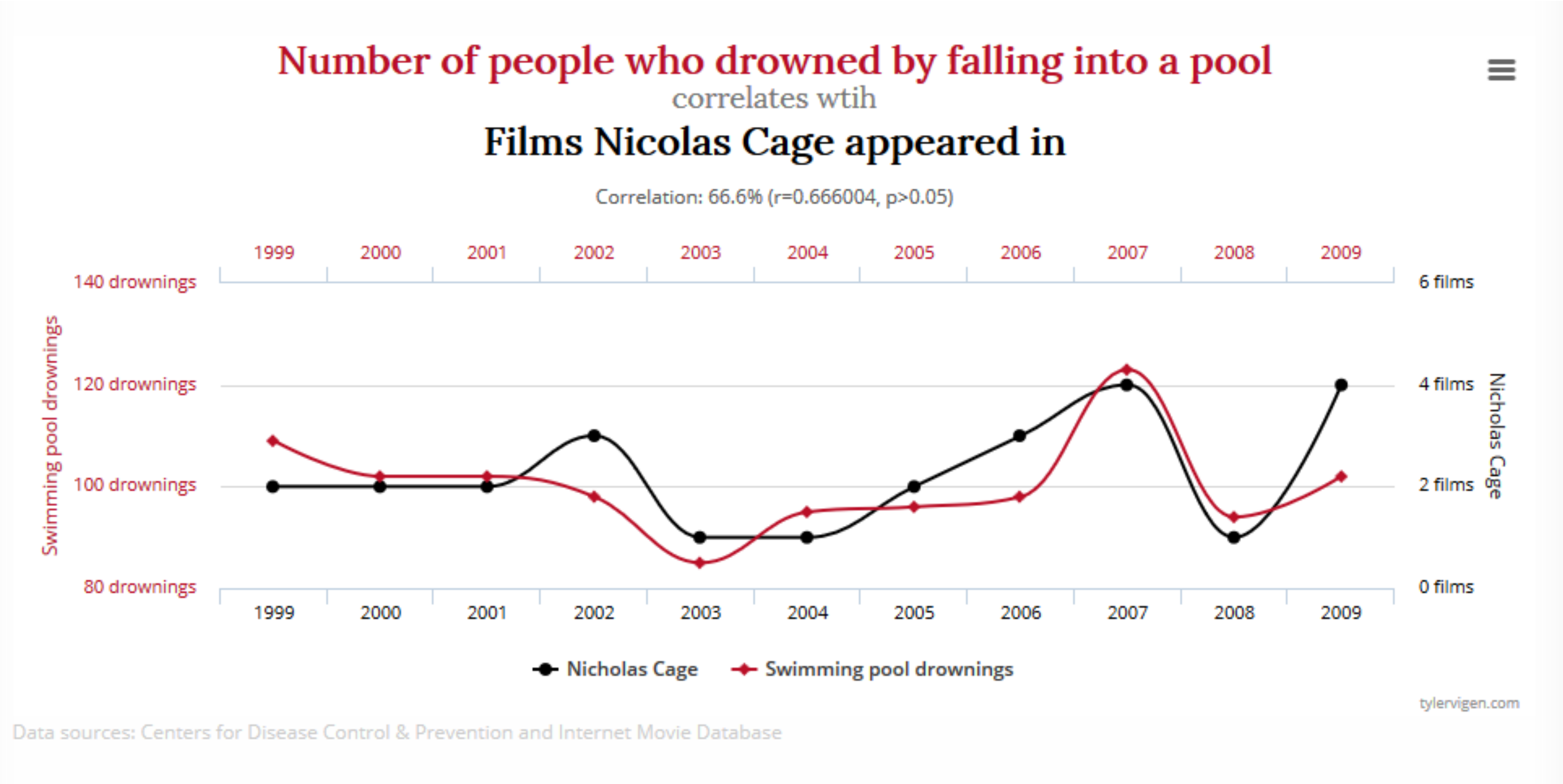

Sup

Behavioral paradigms: correlation

- Correlation versus causation

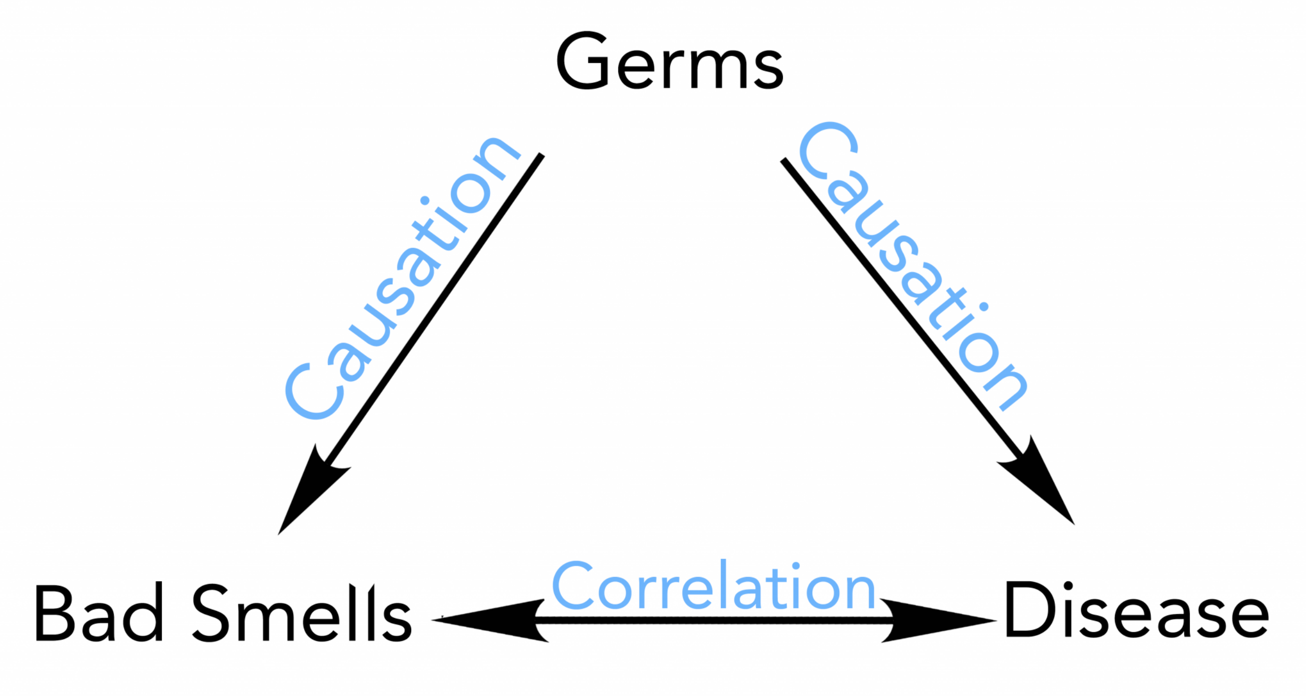
Behavioral paradigms: correlation

- Correlation versus causation



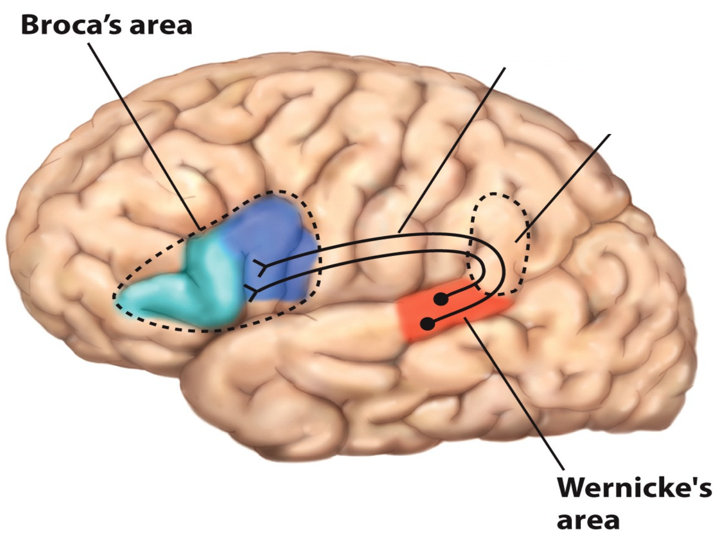
Do Nicolas cage movies *cause* swimming pool drownings?

Correlation does not equal causation



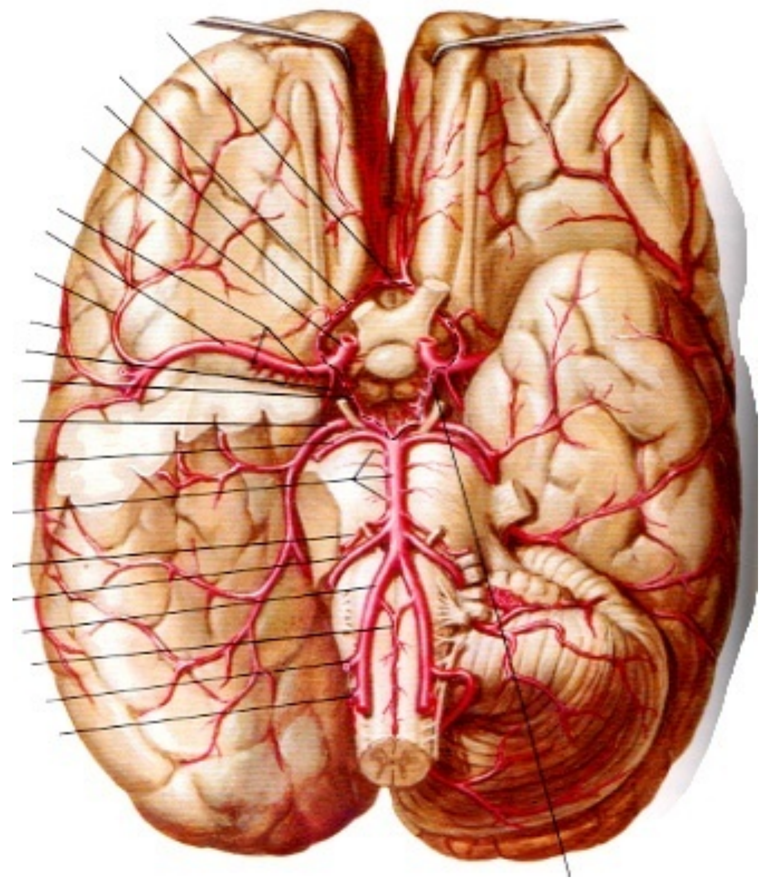
Case studies

- Jargon
  - Lesion – any damage to the brain
  - Necessary versus sufficient
    - Lesion in Broca's area leads to a deficit in language production
      - Necessary, but is it sufficient?



Case studies

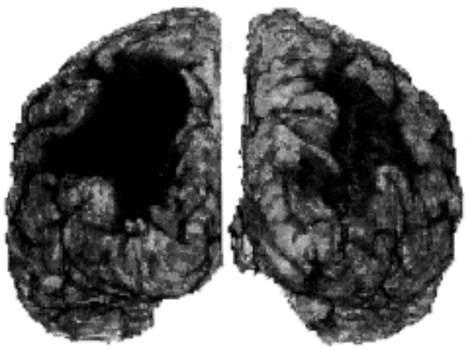
- Test whether a particular brain region is *necessary* for a cognitive function
- Common causes of lesions in humans:
  - Stroke, cerebral hemmorrhage, aneurism, anoxia, etc.
  - Head injuries
  - Tumors and their surgical removal
  - Alzheimer's disease, etc.



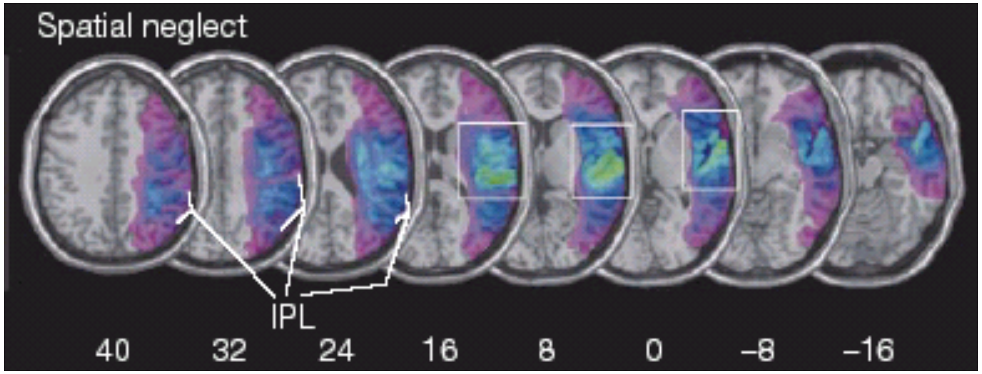
Neuropsychology

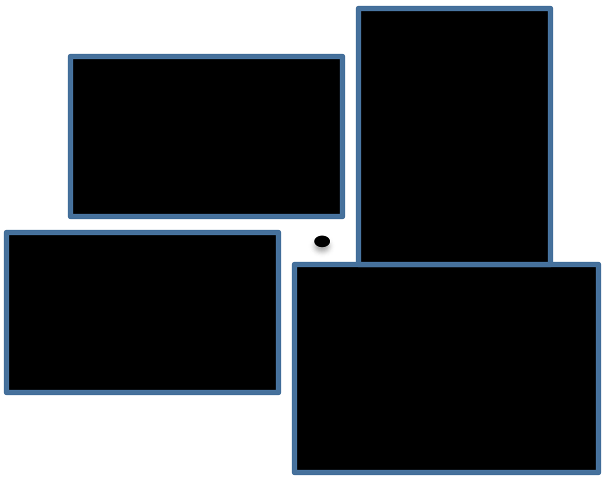
Establish nature of impairments following focal lesions: Look for **dissociations** between impaired and spared cognitive processes

Case studies



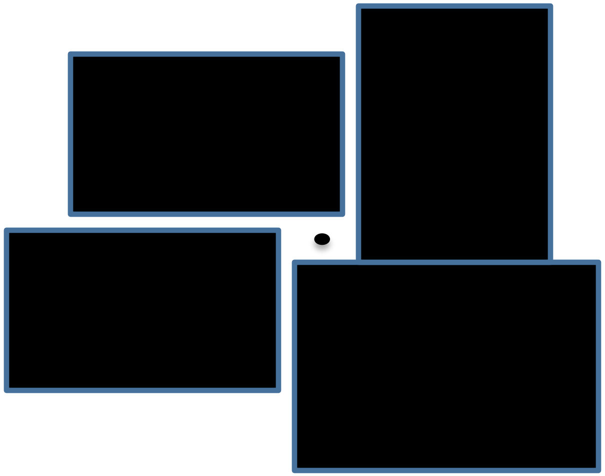
Group studies (area of overlap)





Remember animals and locations:

- object versus spatial memory



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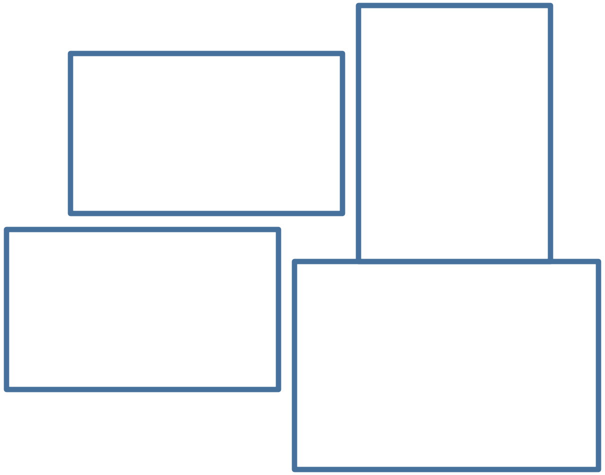
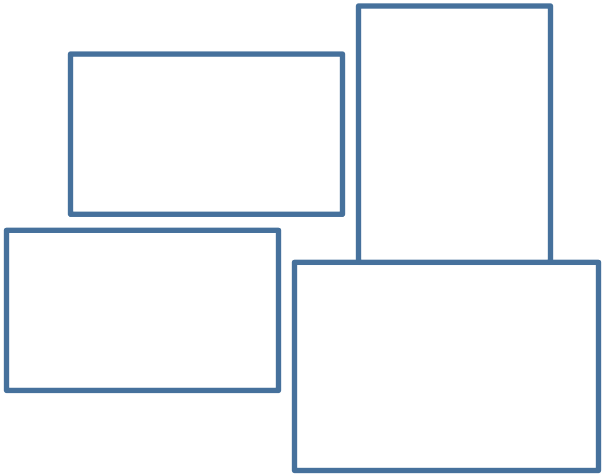
- object versus spatial memory



Where were was the giraffe located?
(spatial)



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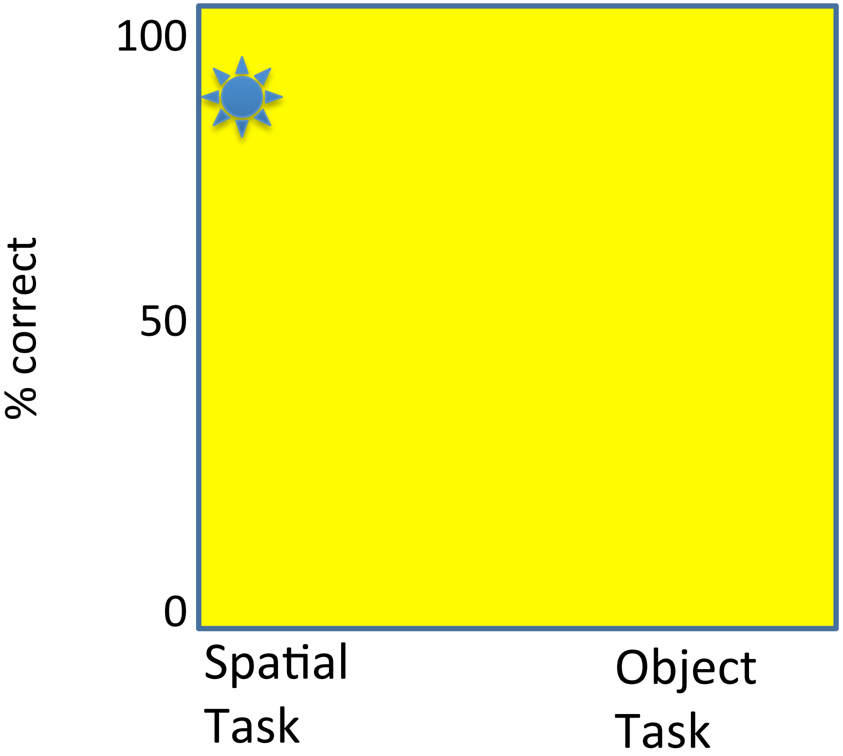

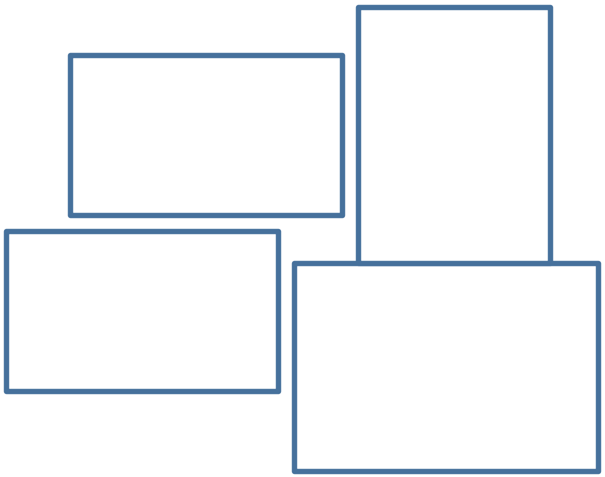

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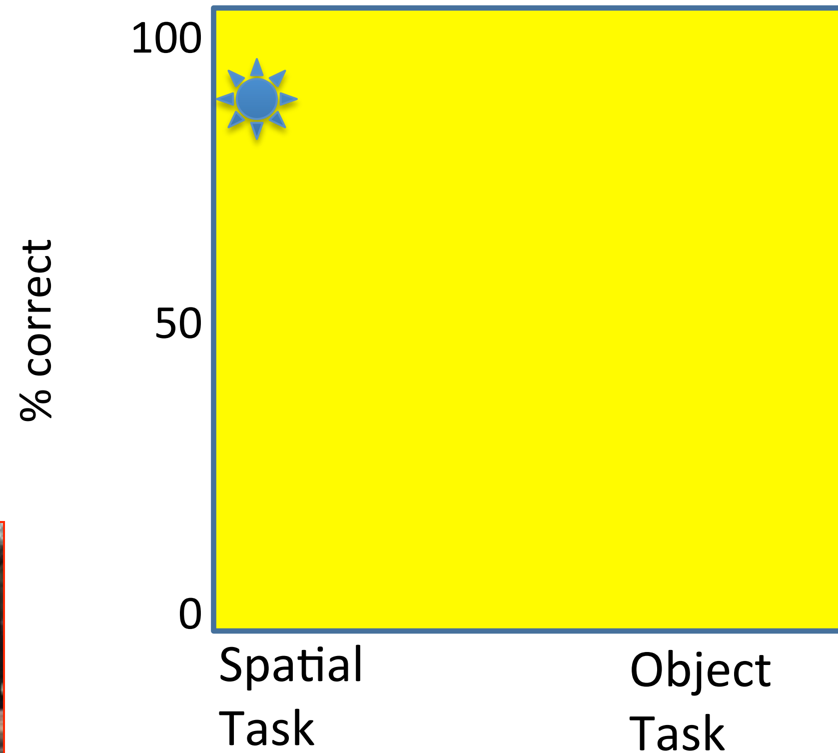
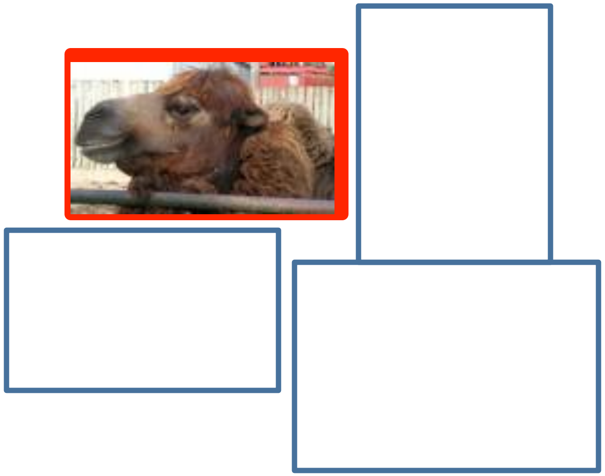
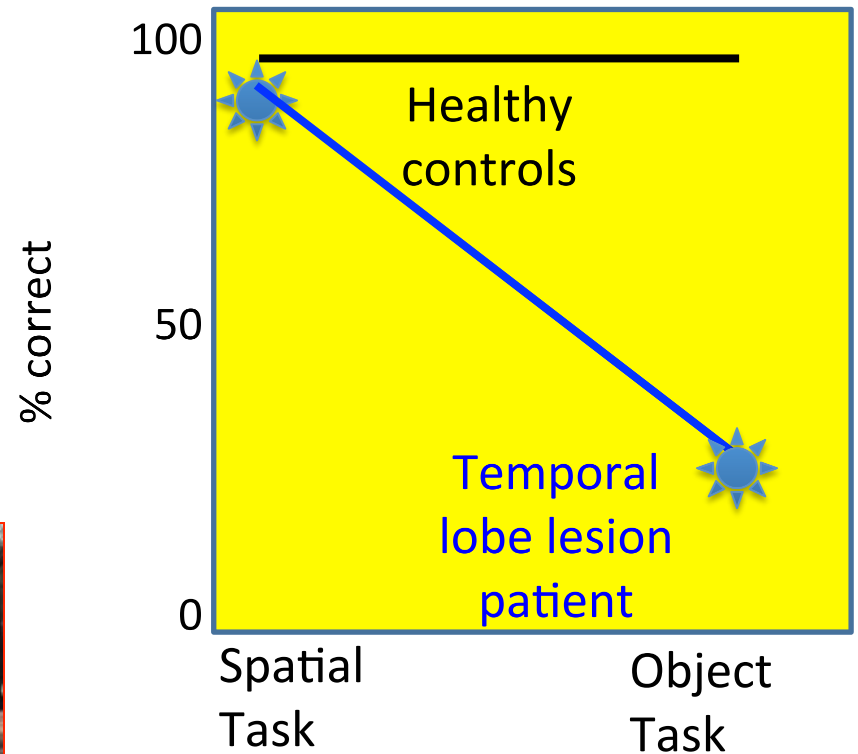


Single dissociation



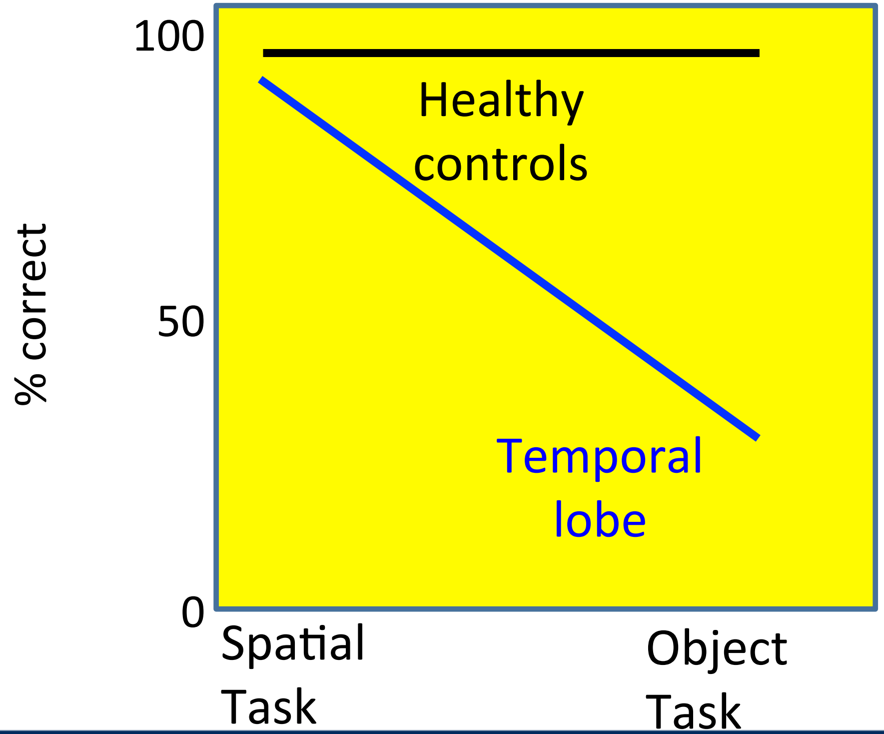


Where were was the giraffe located?
(spatial)

What animal was in top left box?
(object)

<u>Is the spatial task too easy for everyone?</u>

- Problems with single dissociation
  - Is the object task simply harder to score because there are more possible answers?
  - Do patients fail the object task due to general effect of brain damage (e.g., same deficit from other brain lesions)?



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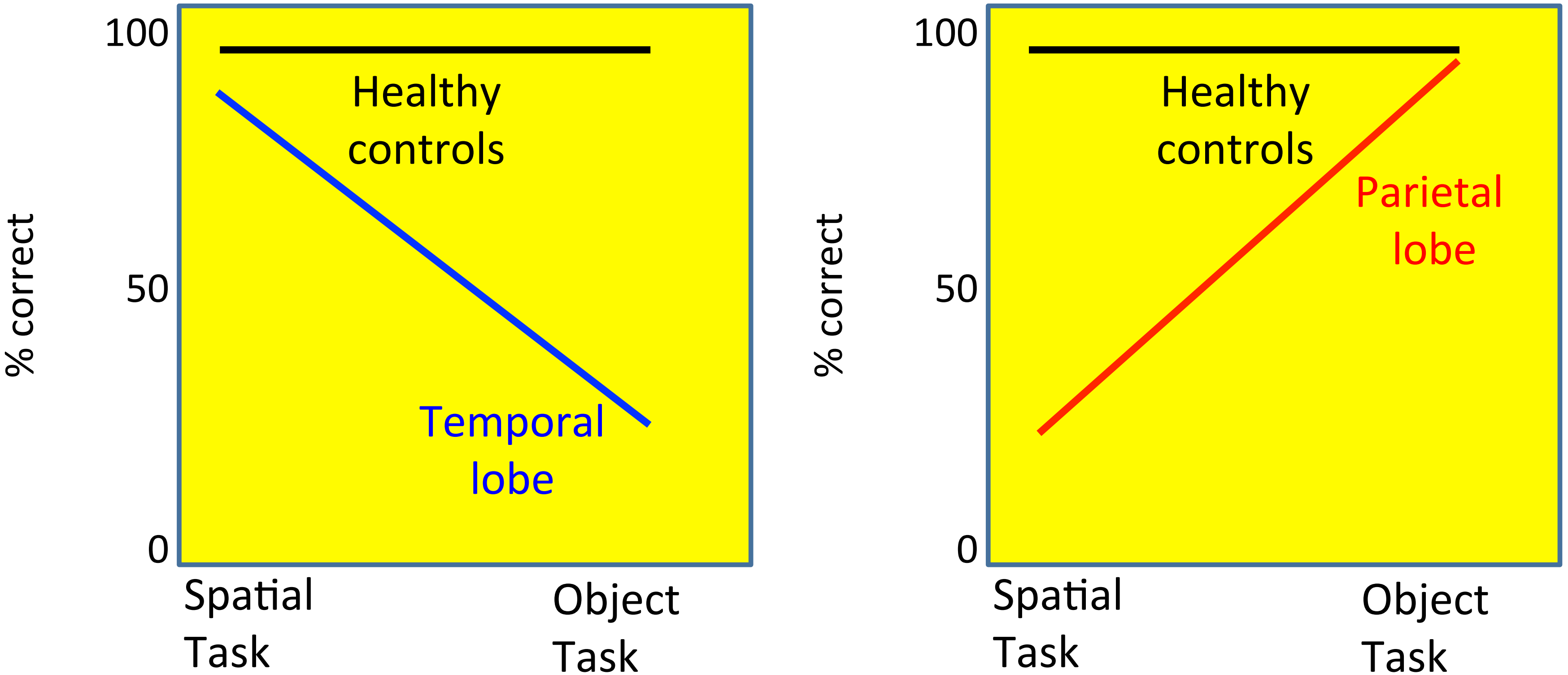
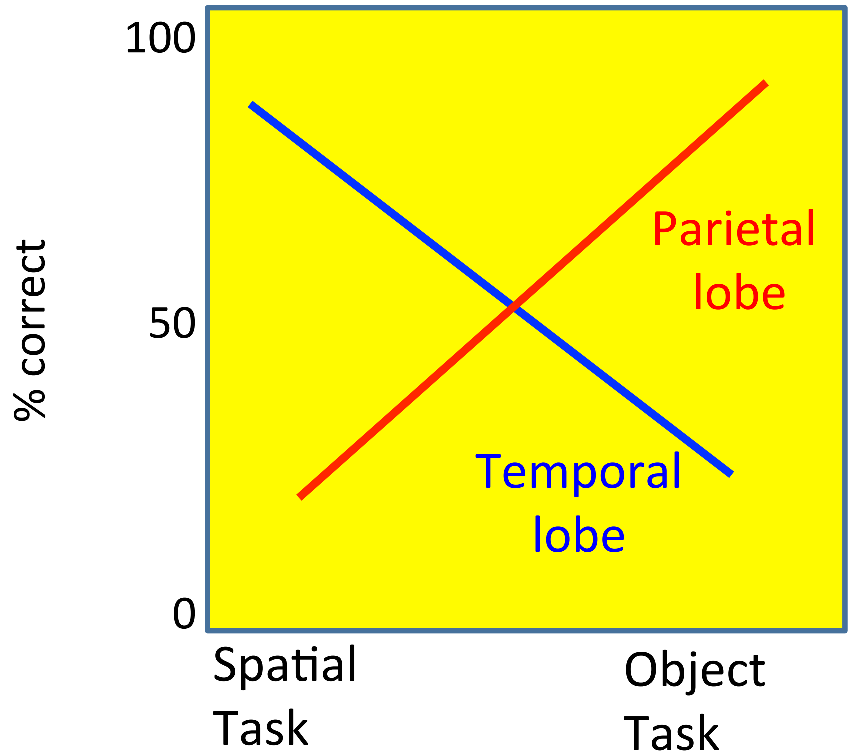
Double dissociation



Double dissociation

Cross-over

Cross-over interaction shows independence in process is not due to un-controlled experimental factors



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Lesions, brain stimulation, brain imaging of a brain area

	Function C	Function D	
Brain area A lesion	X	✓	Single dissociation
Brain area B lesion	✓	X	Single dissociation

Together – double dissociation

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Lesions, brain stimulation, brain imaging of a brain area

	Function C	Function D	
Brain area A Lesion	X	✓	Single dissociation
Brain area B Lesion	X	✓	Single dissociation

Together – two single dissociations

NOT a double dissociation

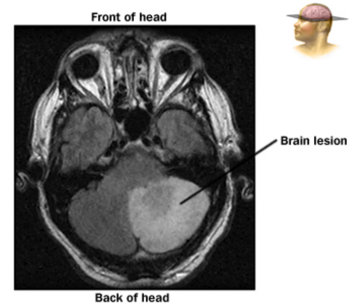
Lesions, brain stimulation, brain imaging of a brain area

	Speech Production	Speech Comprehension	
Broca's area	X	✓	Single dissociation
Wernicke's area	✓	X	Single dissociation

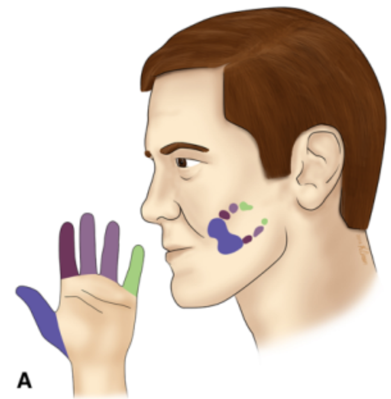
Together – double dissociation

Neuropsychology issues

- Damage is often wide spread



- Neural plasticity may mask deficit



- Deficit could be due to connection

----------→ Wernicke's area

Neuropsychology

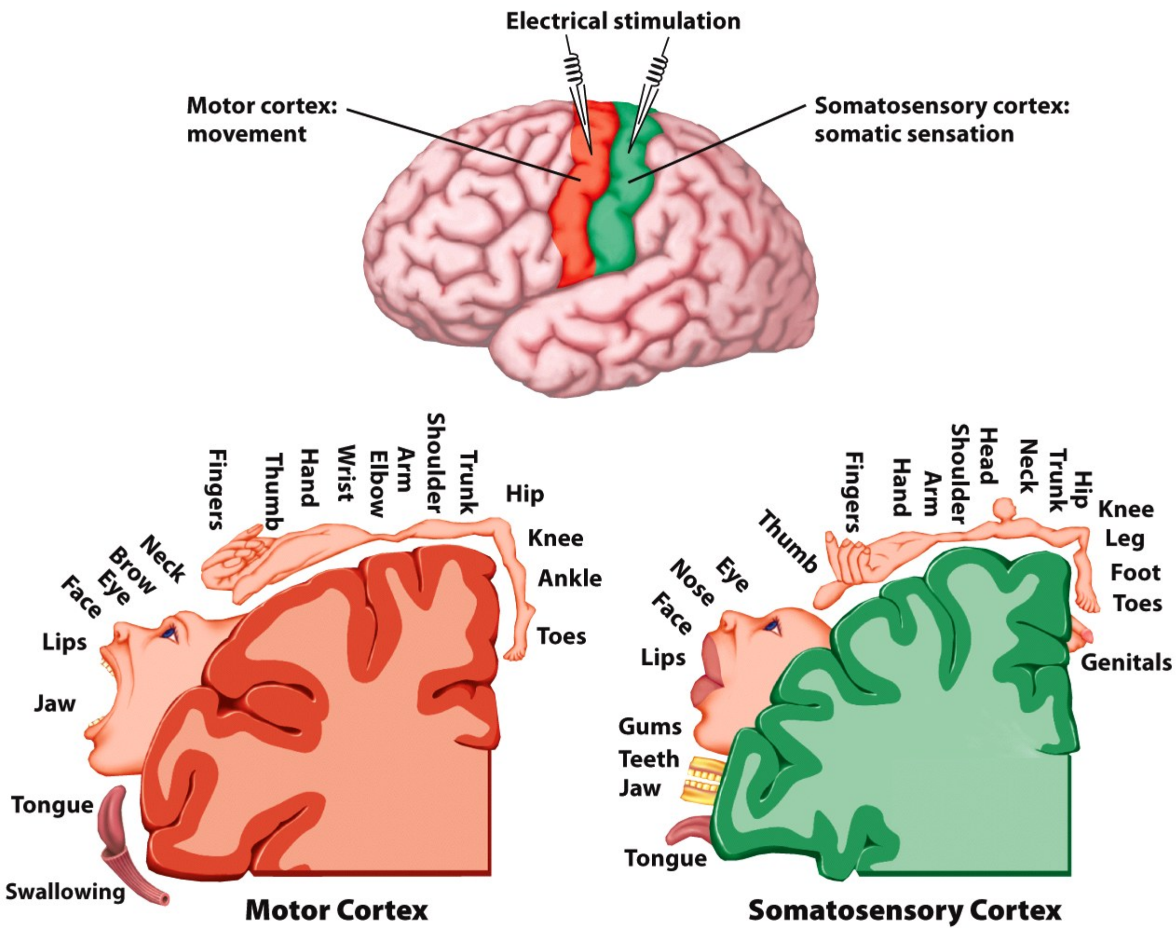
Strengths	Weaknesses
Powerful method for determining whether a region is necessary for a cognitive function.	Human lesions are rarely restricted to a single area, so inference for anatomical correlate is often weak (Group studies are hard b/c patients differ).
Compelling (fairly causal).	Neural plasticity/ compensatory strategies could mask a cognitive deficit.
	Don’t know if damaged region is of primary or secondary importance for function (connectivity).(i.e., whether or not it is sufficient for the function).

Animal Lesions

- Lesions can be created anywhere in animals and with great precision
  - Permanent lesions (e.g., chemical)
  - Reversible lesions (e.g., cooling)

Strengths	Weaknesses
Precise area/ type of damage	Inference to human cognition/ anatomy unclear.
Lesions can be anywhere	

Invasive brain stimulation

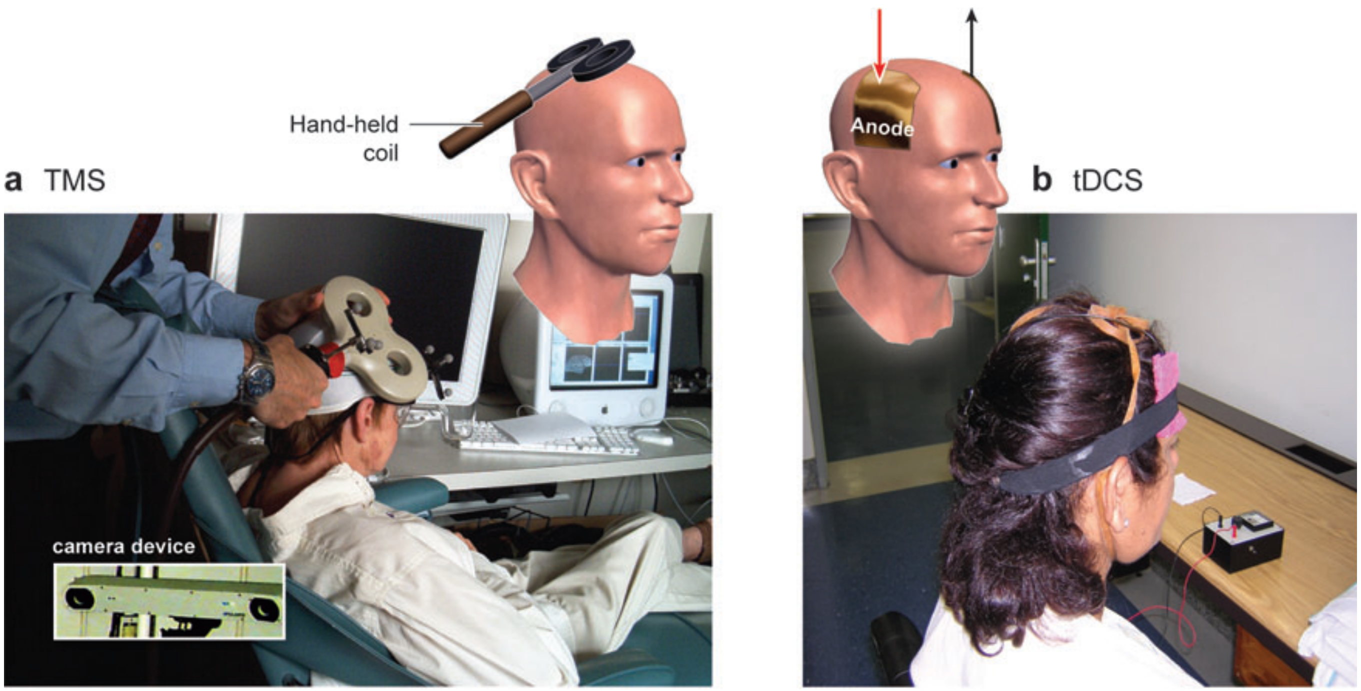


Somatosensory
homunculus

Invasive brain stimulation

Strengths	Weaknesses
Precise temporal and spatial stimulation	Invasive
See direct and “downstream” effects of regional activity	
Causal relationship	

Non-invasive brain stimulation (NIBS) TMS & tDCS

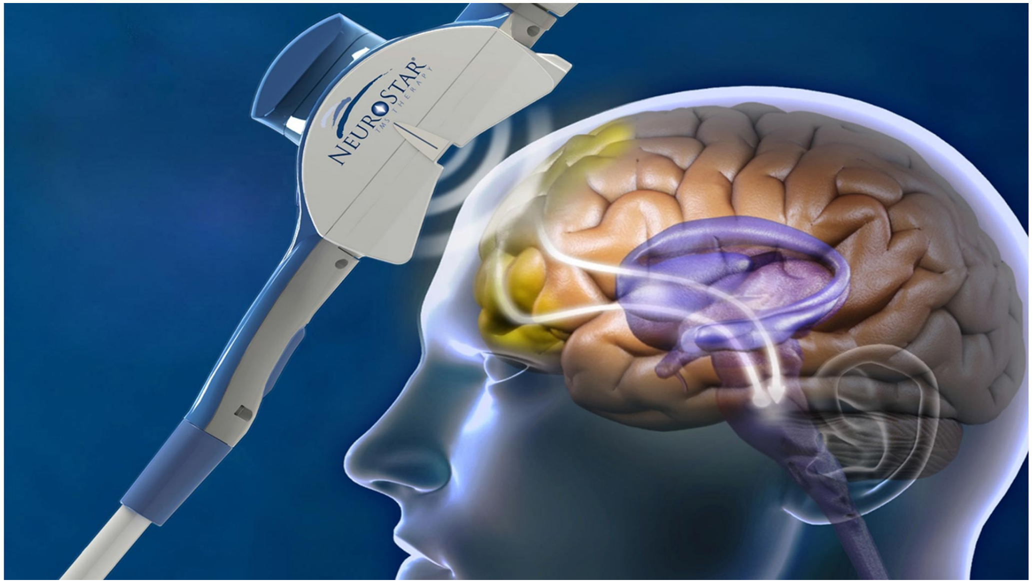


Causal inference – if I mess with this brain region, it causes in a difference

(Wagner et al., 2007)

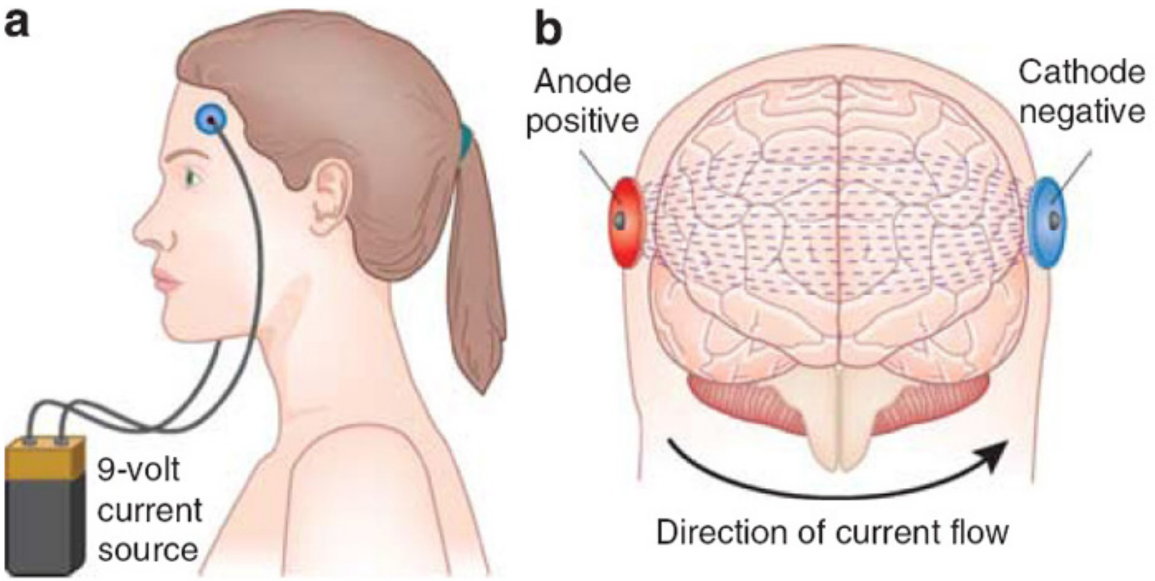
Transcranial magnetic stimulation (TMS)

- Shallow – only reaches a few cm into brain
- Local – pulse is highly localized to what you are aiming at



Transcranial direct current stimulation (tDCS)

- Deep – stimulation can reach deep brain structures
- Non-local – stimulation hits many brain areas at once



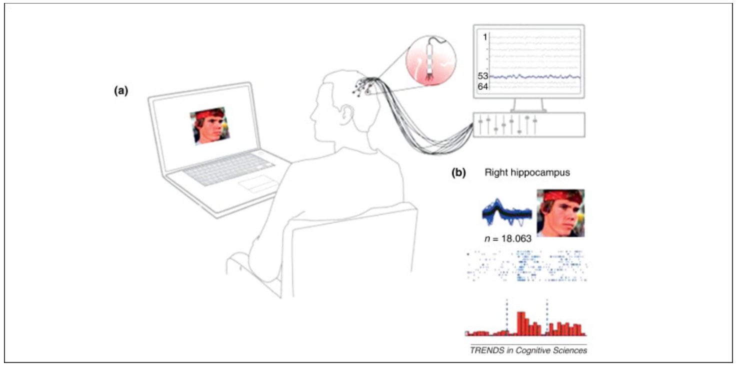
TMS and tDCS in humans

Strengths	Weaknesses
Good temporal resolution: as fast as 20 ms (single TMS pulse) Short term stimulation (~15 min) with long lasting effects	Limited to surface of brain; area activated depends on tilt of coil, placement of electrodes and physical topography of brain (individual differences)
Spatial precision: diff. effects for sites 1-1.5 cm apart	Mechanisms of stimulation vs. disruption not totally understood
Non-invasive	
Find *causal* relationship	

Methods

- Brain imaging
  - Temporal resolution – precision in *time*
    - High temporal resolution - know exactly *when* something happened (ms range)
  - Spatial resolution – precision in location
    - High temporal resolution - know exactly *where* something happened (ms range)

Imaging



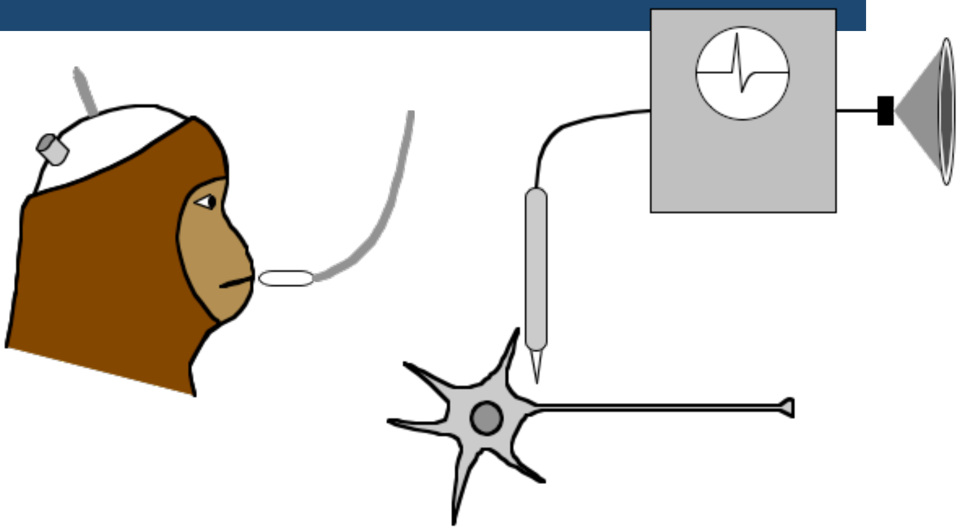
- Single-cell recordings

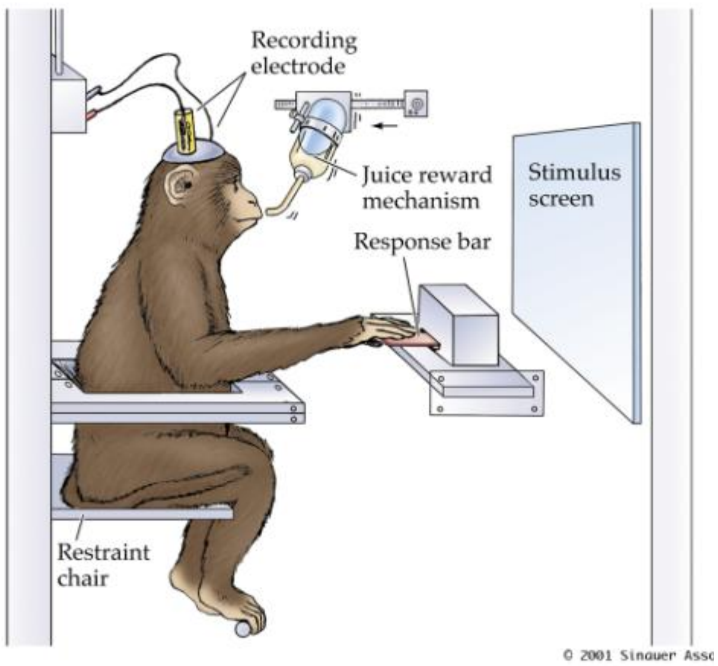
- EEG

- fMRI

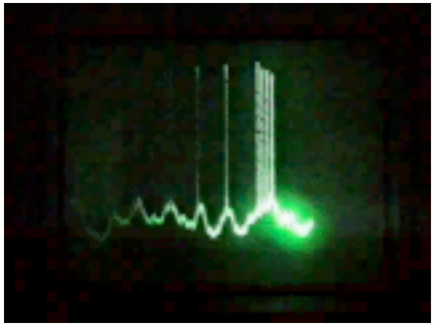
Single unit recording

Measures response properties of neurons under different experimental conditions





Tip of electrode just outside cell body: record (listen without poking cell)



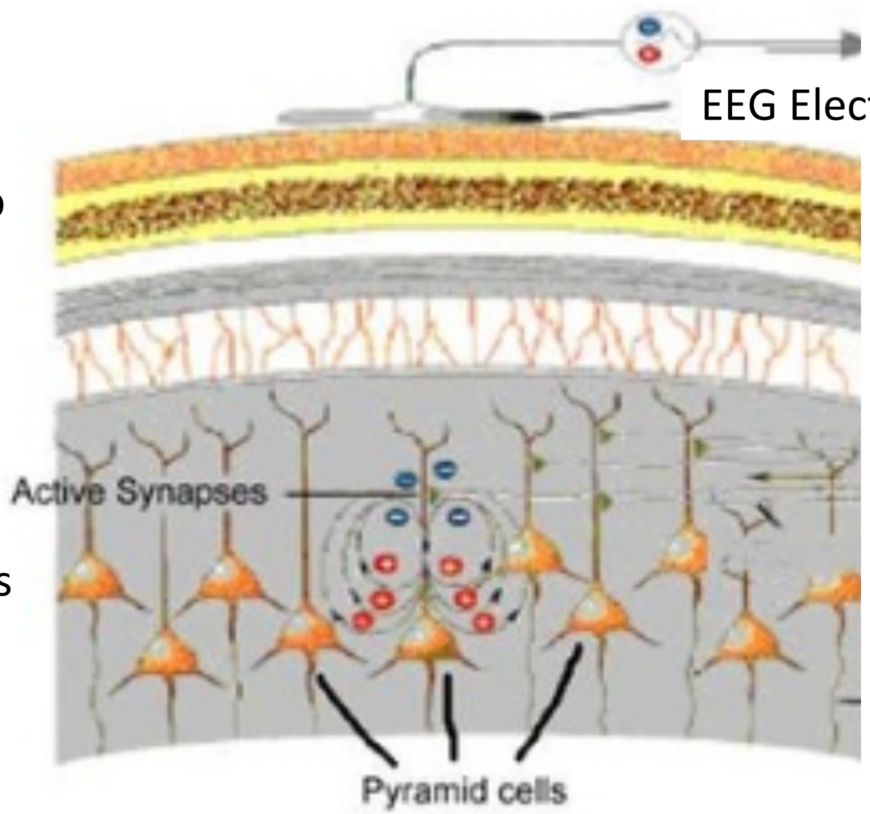
High spatial and high temporal resolution

Single-Cell Recording

Strengths	Weaknesses
Powerful method for examining fundamental units of information processing.	Hard to examine interactions between brain areas.
Spatial and temporal precision.	Animals highly overtrained.
	Fairly inaccessible in humans.

The Electroencephalogram (EEG)

Measures changes in electric field potentials caused by neural activity



High temporal resolution
Low spatial resolution

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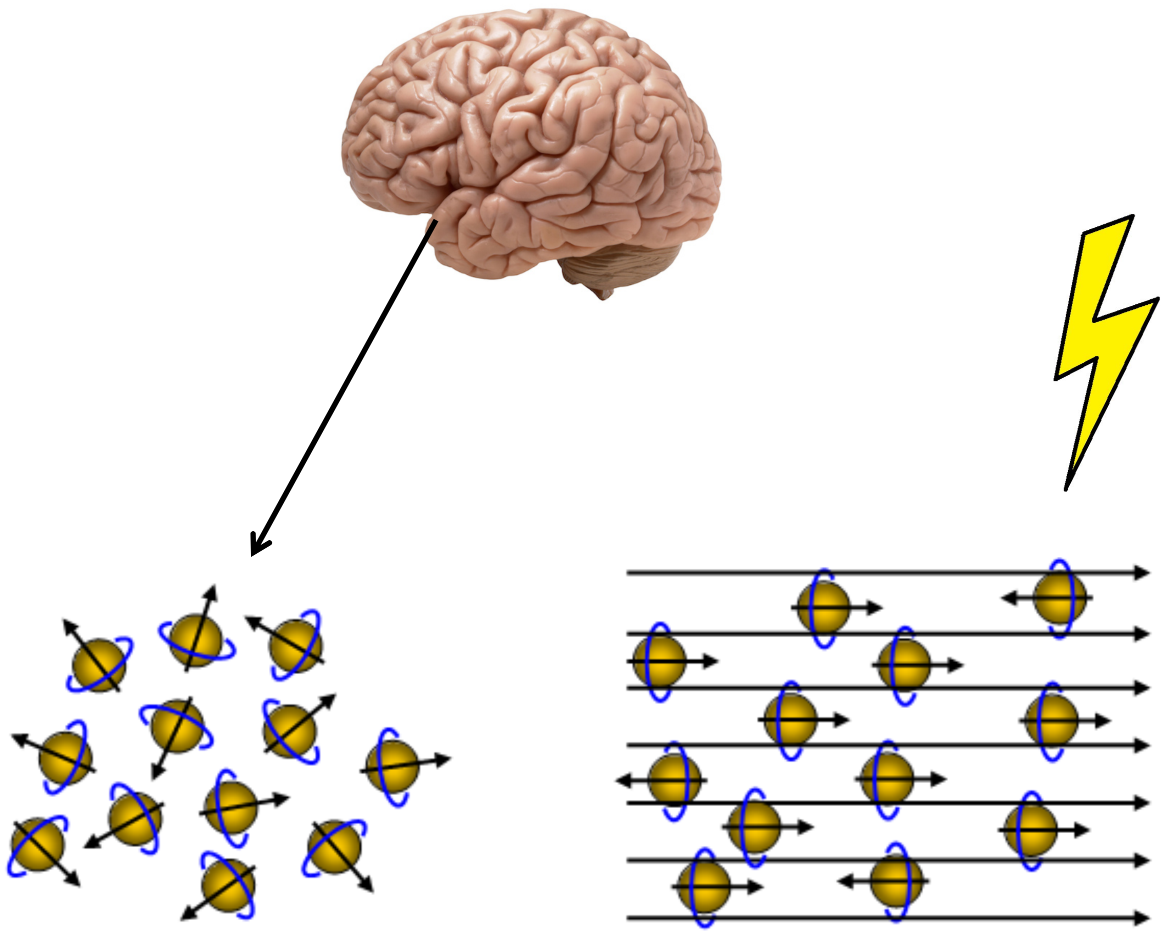
EEG

Strengths	Weaknesses
Temporally precise activity related to neural signal underlying cognitive process	Measure large populations of neurons due to diffusion of electrical signal by skull
Non-invasive	Localizing source of signal is hard
	Need to average a lot of events to get clear event-related potential

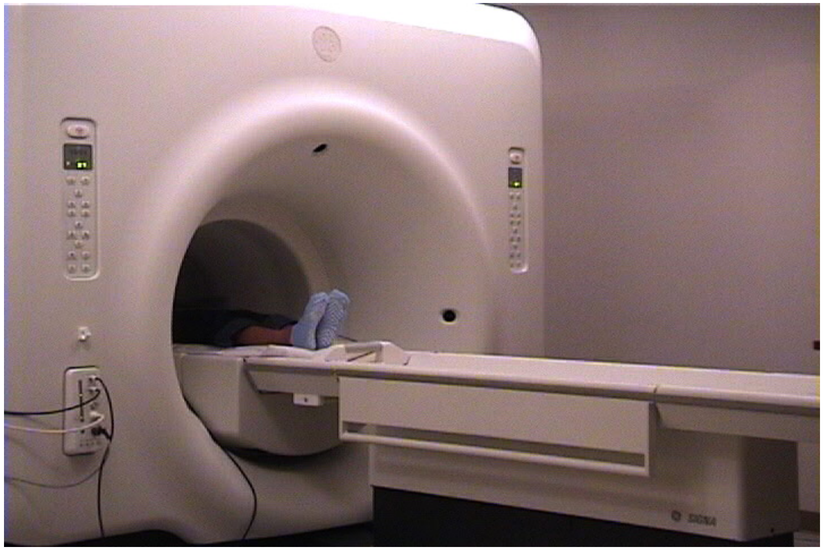
Magnetic Resonance Imaging (MRI)



Without magnetic field

With magnetic field

Magnetic Resonance Imaging (MRI)

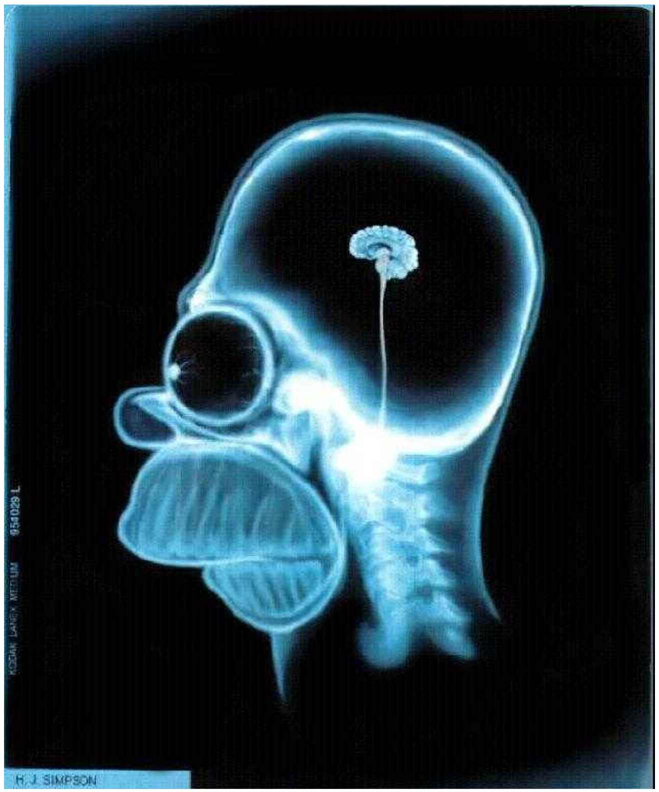


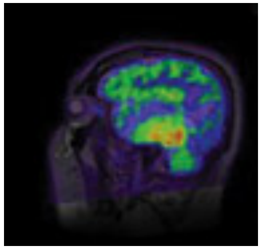
-strong magnetic field
-protons in the brain align with magnetic field
-radio wave perturbs alignment in “slice”
-detectors pick up the signal of protons returning to orientation of magnetic field
-different tissues have diff densities of protons and relaxation rates

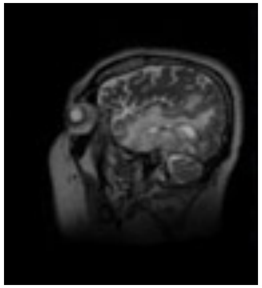
Magnetic resonance imaging (MRI): structural and functional

MRI (or 'structural MRI') studies brain anatomy.

Functional MRI (fMRI) studies brain function



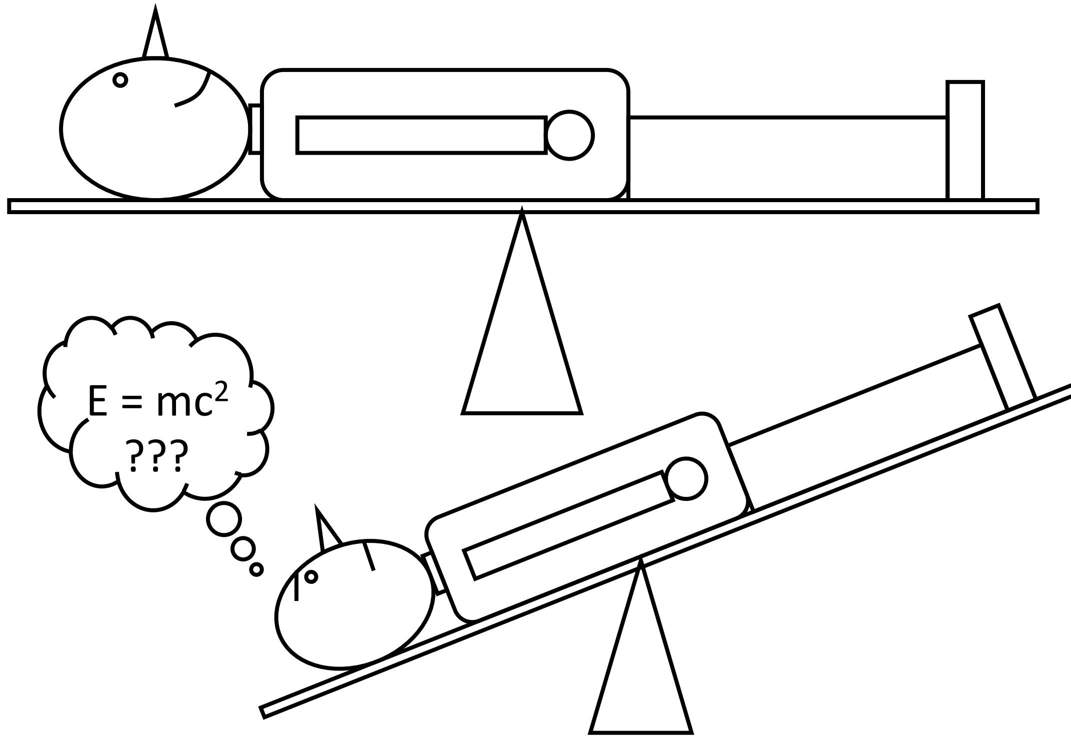




How to get this assuming no direct way of measure neuronal activities?
Indirect: "light up" – energy consumption by refrigerator light
neuronal activities consume energy!

The First Functional "Brain Imaging"

Angelo Mosso
Italian physiologist
(1846-1910)

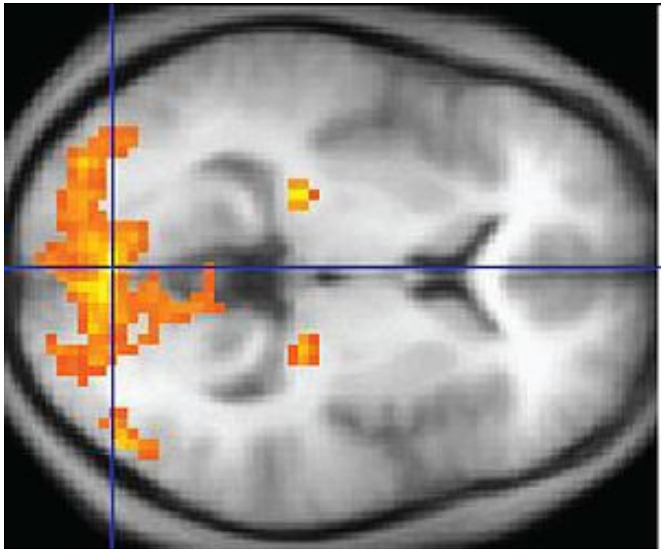


"[In Mosso's experiments] the subject to be observed lay on a delicately balanced table which could tip downward either at the head or at the foot if the weight of either end were increased. The moment emotional or intellectual activity began in the subject, down went the balance at the head-end, in consequence of the redistribution of blood in his system."

-- William James, *Principles of Psychology* (1890)

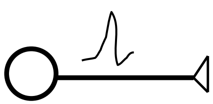
Functional MRI (fMRI)

- Looks at the blood oxygen dependent signal (BOLD)
  - Tracking where the blood is dumping oxygen
  - Blood takes a little while to get to site, so low temporal resolution
  - High spatial resolution

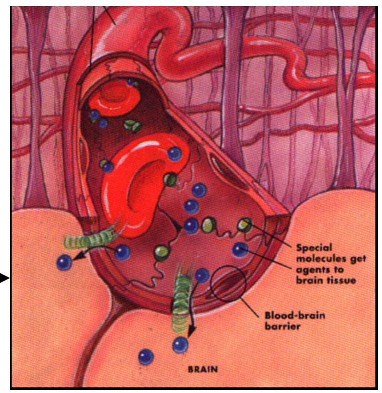


Neural Basis of BOLD

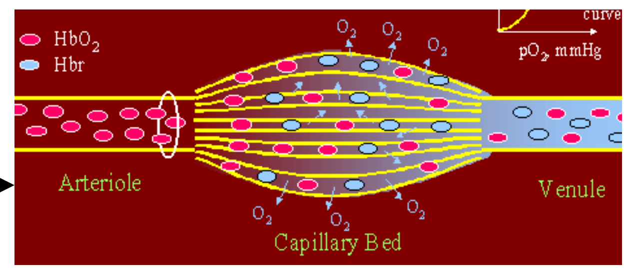
- An *indirect* measure of neural activity
- Based on fact that oxygenated and deoxygenated blood have different magnetic properties



Increased neural activity



Increased blood flow



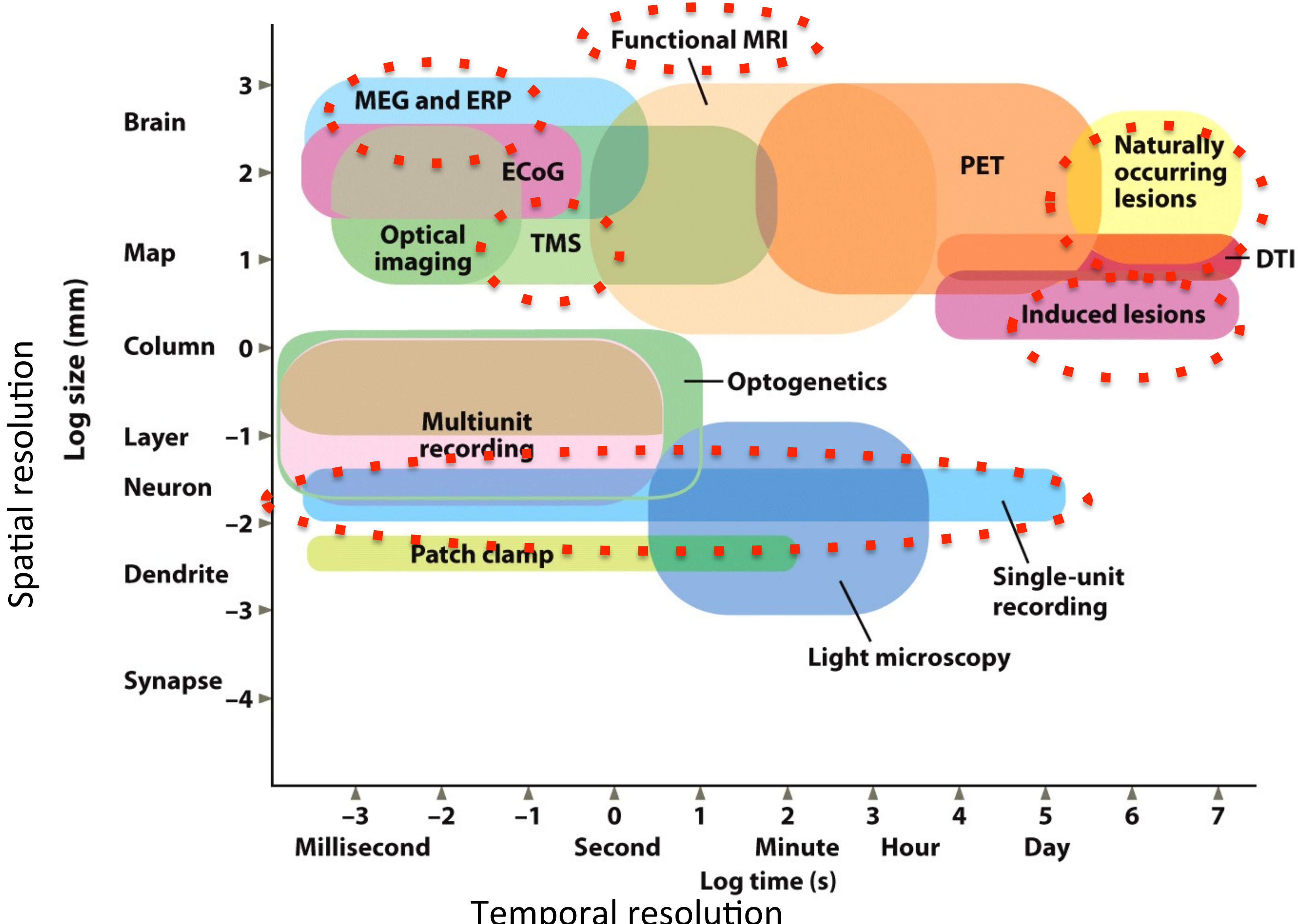
- Surplus of freshly oxygenated blood

Increased BOLD signal

MRI and fMRI

Strengths	Weaknesses
Spatially precise, low temporal, and non-invasive.	For functional scans, signal is relatively slow. Hard to dissociate events that occur nearby in time – difficult to infer causality.
Can look at functional networks of areas over whole brain	Expensive.
Anatomical and functional properties.	Indirect measure of neuronal activity

Temporal and Spatial Resolution



Which method is best?

- I want to know the *causal* relationship between occipital lobe and vision
  - Brain stimulation (tDCS, TMS)
  - Imaging studies are correlational only
- I want to manipulate a deep brain structure non-invasively.
  - tDCS – non-invasive and can reach deep structures

Which method is best?

- Does attention affect early perception or late perception?
  - EEG (high temporal resolution)
    - Used for finding when something occurs
- Are faces and houses represented in different areas in temporal lobes?
  - fMRI (high spatial resolution),
    - Used for locating brain regions

Review

- Syllabus
- Why cognitive neuroscience
- Methods
  - Behavioral
  - Case studies
  - Neuropsychology
  - Brain stimulation and imaging